PROCEDURE AND APPARATUS FOR COLLECTION OF FREE METHANE GAS FROM THE SEA BOTTOM

The present invention is referring to a procedure and apparatus for collection of free methane gas from the sea bottom destined to catch and liquefy the released methane gas from metastabile of methane hydrate situated on the seas and oceans bottom.

Following the increased interest of world's wide regarding the research efforts on getting the methane gas, a multitude of hydrate formation zones were discovered on the seas and oceans bottom bed, from which was found a multitude of metastabile zone of methane hydrate without lithologocal cover. If only a small fraction of this free methane gas from the seas and oceans bottom would be collected, it could constitute a significant energy resource as a fuel.

It is not known a procedure for collection of methane gas released from zones of metastabile gas hydrate deposits from the sea bottom. It is not known an apparatus destined to free methane gas collection released from deposits of hydrate gas from the sea bottom.

The matter that is resolved by the invention is the realization of a procedure and an apparatus, which will allow the free methane gas collection from the bottom of the sea.

The procedure for collection of free methane gas from the bottom of the sea, according to the invention, eliminate the above mentioned disadvantages, because it is constituted from a first operation in which the collection of free methane gas from the bottom of the sea takes place and it is directed upwards, to a running section of methane gas, together with the sea's water and forming a mixture of methane gas-sea water. The shifting of mixture is done under a form of a current tube up to a room in which is taking place the separation phase, in which the mixture overflows at a level inferior to the sea's level, where the pressure is smaller than the one of the sea's bottom, and where is taking place a distribution/gravitational dispersion of it on a big surface on which the running is done at a more reduced pressure, which allows the separation of methane gas from water. The humid methane gas is collected at the room's superior part and the sea water is running freely towards an inferior level, from where, in the following operation, is absorbed and evacuated back in the sea for insuring the required level difference for the mixture's

raising. In the following operation, the humid methane gas, captured at the superior room's part, is absorbed towards an other room where is cooled to reduce the condensation of the last fraction of sea's water, operation after which are obtained sea water in liquid state which is collected and then evacuated and dry methane gas. In the following operation is proceeding to the methane cooling at required temperature for its passing from gaseous state into liquid state. The procedure, in an other version of realization, comprises a first operation in which the humid methane gas, brought to the sea's surface is cooled in a room by bringing it in contact with cooled methane gas and by mixing it with this. Due to the diminished temperature it is taking place the condensation of the last fraction of the sea's water vapors and is getting the dry methane gas.

This operation is followed by the compression, in a first stage, up to a certain pressure and temperature, after which, to an other operation is cooled at sea water temperature. Follows a second compression stage, followed by a new cooling at sea temperature and by that the third stage of compression, in a last operation the methane gas discharged after this last compression being sent to a room where, after lamination followed by an adiabatic expansion, is passing from a gaseous phase to a liquid phase.

In parallel with the above operation, an other phase occurs, in which a part of compressed methane gas in first stage is taken to produce the absorption of liquid methane obtained according with the last operation. Following to this absorption, the compressed hot methane gas from the first compression stage is mixed with the liquid methane and is discharged into a room in which is taking place a first cooling of methane gas arrived following the operation of its water separation. The apparatus for collection of free methane gas from the sea bottom, according to the invention, is made from some guiding arms, set-up in crosswise position, on which are sitting an intermediary platform, destined to support some electrical reversible trolleys, used for radial and vertical direction displacement of a flexible or telescopic conduit and of some collectors for mixture, some double reversible trolleys with the help of which some water separators and a flexible conduit can be vertically and radial driven, and the flexible conduit is supported on its horizontal portion by some floating caissons, as well and of some double reversible electrical trolleys used to change the position of some lateral anchors.

An inferior platform, together with the intermediary platform, is destined to support the components of some technological lines, and a superior platform serves to alight or take off for the helicopter. Some sloping portion of guiding arms serve to support the three specified platforms and its superior ends are rigidly connected and keep up a hoist to stretch out a central anchor. Under each guiding arm is seating a water separator connected at its inferior part through a telescopic conduit with the collector of mixture, and on intermediary and inferior platform are located corresponding to the water separators and connected to them through the flexible conduits, the mentioned technological lines. The guiding arms are provided with some horizontal portions supported by some floating caissons, at the ends of each arm being located some helix, so that at their putting in operation to do a couple which to rotate the entire ensemble around the vertical axis, materialized by the central anchor's rope. Rigidiness of the showed guiding arms is done with the help of some ropes stretched between the exterior ends of its horizontal portions. The inferior and medium platforms have an octagonal form and are provided with an opening. Each of the water separators are provided with a parallelepiped corps closed at the superior part with a cover and sitting on a submarine platform sustained by some floating caissons. Inside is placed an horizontal plate which defines an inferior and superior room, on plate being mounted an overflow sleeve, connected at its down end to a telescopic conduit and some guiding tubs through which vertical is running the ropes through which is achieving the supporting of telescopic conduit and the mixture collector.

At the superior part of parallelepiped corps are sitting some screens for separation and on the same submarine platform are also sitting some pumps for evacuation. The hanging up of water separator is realized through some ropes, time in which the seating of mixture collector close to the sea bottom is done through some legs. Each of technological lines is provided with an extractor of humidity from methane, connected to the bottom with a conduit through which the condensate is eliminated and upper part, through other conduit, the dry methane gas is passing towards a methane gas liquifier, from which is running in the liquid state through a conduit in a storage tank. A compressor for nitrogen drive the nitrogen in gas state through a valve of lamination towards a tank of liquid nitrogen from where, the becoming liquid nitrogen is running towards some serpentines

of methane liquidifier and respective water extractor. The turbo compressor is driven by a turbine with gases, which is driving and an electrical generator also. The reversible electrical trolleys are provided with some ropes supported and guided with the help of some guiding rolls and of one block of rolls. The apparatus, in an other version of realization, is provided with an other technological line equipped with an other extractor of humidity, connected through a conduit to the water separator, which is placed on an inferior platform and connected through other conduit to some turbocompressor in steps. They are situated on the same axis of a turbine with gases, which is coupled with an air compressor, and with an electrical generator, between turbocompressors being inserted some coolers. The turbocompressor is connected through a conduit with a tank of liquid methane provided with a valve for lamination, between the water extractor and the liquid methane tank being placed an ejector in which the aspiration is realized through a conduit through which the methane gas is brought from turbocompressor.

By using the invention, the following advantages are acquired:

- The use of a big source of combustible which will reduce the effect of the energy needs.
- The diminution of the atmosphere pollution.

In the following is presented an example of invention's realization in connection with figures from 1 to 10, which represent:

- Fig. 1, general lateral view of apparatus for collection of free methane gas from the bottom of the sea, according to the invention;
- Fig. 2, the kinematics sketch for driving anchors collectors and of methane gas separators, afferent to each guiding arms, according with the invention;
- Fig. 3, the technological line of methane gas liquefaction, in first version of realization, afferent to each guiding arm, according to the invention;
- Fig. 4, lateral view of apparatus, according to the invention, making evident the connection between the collector and separator of methane gas and technological line afferent to a guiding arm;
- Fig. 5, section with a plane I-I from Fig. 4;
- Fig. 6, section with a plane II-II from Fig. 4;

- Fig. 7, section with a vertical plane through the collector and through the methane gas separator;
- Fig. 8, section with a horizontal plane III-III from Fig. 7;
- Fig. 9, section with a vertical plane IV-IV from Fig. 8;
- Fig. 10, the technological line of methane gas liquefaction, in other version_of realization, afferent to each guiding arm, according to the invention.

The procedure for collection of free methane gas from the sea bottom, in a first version of realization, according to the invention, starts with a first operation in which is taking place the collection of saturated mixture formed from sea water and methane gas and of free methane gas emanated from metastabile deposits from the sea bottom, from a big surface and of them upwards direction to a narrow running section towards sea's surface.

The water-methane gas mixture, which is rising continuously from the sea bottom based on the vessels communication principle, is over flown, in the next phase in a room, at an inferior level of the sea's level, where the pressure is smaller than that from the sea bottom and where is taking place a gravitational distribution/spreading of it on a big surface on which the running is done on a thin stratum. In these conditions, the separation of methane gas and water is done, the humid methane gas is collected at the superior part of room and the sea water is running freely towards an inferior level from where, in the next operation, is sucked and evacuated back into the sea.

The humid methane gas is then cooled, in an other room, by being in contact with a continuous cooled surface, for the condensation of the last fraction of the sea water vapors to be done, operation after which is obtaining the dry methane gas and sea water in liquid state, water which is collected and then evacuated.

In the next operation the cooling of methane gas is continued, until the required temperature for its passing into the liquid state is achieved, followed by its collection and storage.

The procedure for free methane gas collection from the sea bottom in other version of realization, according to the invention, is showing the modality of liquefaction of methane gas by compression and lamination, followed by an adiabatic expansion. In this way, the humid methane gas brought to the sea surface is cooled in a room by bringing it in contact with a jet of cooled methane gas and by mixing this cooled gas inside of the

mentioned room. Because of temperature reduction is taking place the condensation of last fraction of sea water vapors, operation after which is obtained dry methane gas and sea water, water which after collection is evacuated.

The dry methane gas is sucked and compressed in a first step, up to a certain pressure and temperature, after which, in an other operation, is brought under the sea level where in contact with a surface at sea temperature is taking place its cooling.

These two successive operations of compression and cooling of methane gas are repeated also in the second step of compression. The methane gas so compressed at this second step is cooled too at the sea temperature and then is compressed again in that of the third step.

In a last operation, the methane gas discharged after the third compression is sent to a room where, after a lamination followed by an adiabatic expansion, is passing from gaseous phase into liquid phase.

In parallel with the above described operation of procedure, according to the invention, in this second version of realization, is taking place an other phase, in which a part of compressed methane gas from first step is taken to produce the suction of liquid methane gas obtained according to the last operation. The sucked liquid methane is discharged into the mixture with gaseous methane from the first step of compression towards a room in which, as was shown before, is taking place the first cooling of methane gas coming from water separator.

The apparatus for collection of free methane gas from the sea bottom, in a first version of realization, according to the invention is made from some guiding arms **A** positioned crosswise and provided with a horizontal portion **1** maintained at sea surface level with the help of some floating caissons **2** and which is cotinuing in the central zone with a slopping portion **3**. The floating caissons **2** should be able to take over the statics and dynamics loads caused by the waves and winds so that the apparatus, according to the invention, to be maintained at sea surface level.

The slopping **3** portions are rigidified between them at the superior portion and holding a hoist **4** for stretching a central anchor **5**, a superior platform **6** destined to alight and take off of helicopters, an intermediary platform **B** and an inferior platform **C** which sustain the power actuated elements and other various equipment.

The guiding arms **A** can be made from steel pipes, assembled in lattices, and the platforms **6**, **B** and **C** are provided with steel grills and with balustrades for service personnel's protection. The platforms **6**, **B** and **C** have to be rigidified towards the sloped portions **3** with the help of some beams, pillars, bars and diagonals, but these construction details do not make the object of this invention, being themselves known.

In the same time, the platforms **B** and **C** which have an octagonal shape and each are provided with an opening **a** and respectively **b**, will be placed at a sufficient height so that the sea's waves action to not impeded the worker's activity and the function of the equipment situated the platforms.

Because this entire apparatus, according to the invention, not to be displaced by the sea's currents of waves and winds, it is provided, besides the central anchor **5** with some lateral anchor **7**, one for each arm **A**, connected by ropes.

The apparatus, according to the invention, can be rotated on an horizontal plane, around of central anchor **5**, with the help of some propellers **8** and **9**, driven by some not shown electromotrs, propellers placed diametrical opposite to the exterior ends of two arms **A** with the purpose of producing a couple of rotations of the entire ensemble.

The braking of this rotation movement can be done with the help of some other propellers **10** and **11** placed at the exterior ends of the other two arms **A**, diametrically opposed, allowing in this way to choose the desired position of the ensemble. It is obviously understood that, during the rotation operation of apparatus, according to the invention, the lateral anchors **7** should be raised.

To obtain a good stiffness of the guiding arms **A**, the exterior ends are connected between them with some ropes **12**.

On the intermediary platform **B** are placed some groups of electrical reversible trolleys **D**, **E**, **F** and **G**, placed over each of guiding arms **A** and destined for driving the suspended components of respective arm **A**. On platform **B** is also placed a part of the necessary equipment of a technological line **H**.

The first two trolleys **D** and **E** are provided with a rope **13** and respectively **14**, which are running on some guiding rolls **15** and **16** and respectively **17** and **18** as well and on a roll **19** and respectively **20**, placed on a rolls block **J**, the ropes **13** and **14** upholding and

permitting the vertical position modification of a collector **K** of mixture and of a conduit **21**.

The third electrical reversible and double trolley **F** id driving a rope **22** which is passing over some guiding rolls **23**, **24** and connected with frame **25** placed on block **J**, from where an other rope **26** is rolling on a guiding roll **27**, then on a guiding roll **28** placed on block **J** and on some guiding rolls **29** and **30**, rope **26** which allows the radial displacement along the arms **A**, of block of rolls **J** of a water separator **L**.

The trolleys **G** also double, is driving a rope **31** which is rolling on some rolls **32** and **33**, on a roll **34** placed on block **J** and then on a guiding roll **35** being connected at the inferior end of lateral anchor **7** and permitting its vertical movement.

An other rope **36** of the same trolley **G** is rolling on some guiding rolls **37** and **38** with the scope of radial displacement and anchoring to the bottom of the sea the lateral anchor **7**.

The water separators **L** are placed under each of guiding arms **A**, being partially submersed in the seawater.

Each of the water separators **L** are provided with a parallelipipedic body **39** closed tight and provided at its superior part with a cover **40**, like a pyramid. The body **39** includes a superior room **c** in which are provided some horizontal strainers **41** and **42** of different sizes which are placed at certain distance one to the other, with the purpose of contributing to the partial separation of the methane gas of water vapors.

In the center of the body **39** is placed an overflow sleeve **43** united with a horizontal plate **44** so that the superior end of sleeve **43** to be situated under the seawater surface level and in the same time, over the plate **44**. The bottom of the body **39** is placed on a platform **45**; platform, which is sitting on some floating caissons 46 and together with plate 44, forms an inferior room **d**.

The sea water-methane gas mixture, which is running from sleeve **43** and is spreading on plate **44** surface, liberates the gas and the water is running through the two ends of plate **44** entering in the inferior room **d**. Some pumps **47** placed close to the body **39** on the same platform **45** suck the water from room **d** and discharge it in the sea.

The superior corners of paralelipipedic body **39** are connected with the help of rope **48** by the rolls block **J**, connection that allows the water separator **L** to move on a radial direction.

The overflow sleeve **43** is connected at its inferior ends with conduit **21**, which can be flexible or telescopic and of which the inferior end was connected to the collector **K**. This one has the form of a pyramid and is provided at its base perimeter with some sitting legs **49** of a certain weight. After the collector **K** positioning over a metastabile zone **e** of hydrate methane, by penetration its legs **49** in the stratum of the sea bottom, its anchorage in a chosen position should be achieved.

The water separators **L** are connected to some aerial flexible conduits **50** of which horizontal portions found under the arms **A** are sitting on some floating caissons **51**.

The ropes, **13** and **14**, which are upholding the collector K, and conduit **21**, are crossing the body **39** of separator **L** through some guiding tubes **52**.

At its superior part, aerial, each flexible conduit **50** is connected through a fixed conduit **53** and a valve **54** with some humidity extractor **M** like a heat exchanger, located on an intermediary platform **B**. The extractor **M** is provided with a cooling serpentine **55**, connected through valves **56** and **57** with technological line **H**, with a valve **58** at its superior part and with a discharge valve **59** at its lower part. From the valve **58** through conduit **60** and a valve **61** the extractor **M** is connected with a liquefactor of methane gas **N** equipped with an other cooling serpentine **62**, provided at its ends with some valves **63** and **64** for entering and respectively exit.

The humidity extractor **M** and the gas liquefactor **N** are located on the intermediary platform **B**.

At the lower part of the liquefactor **N** are sitting a discharge valve **65** which, through a conduit **66** and a valve **67** makes the connection to a storage tank **O** provided with a discharge valve **68**, and sitting on an inferior platform **C**.

The serpentine **55** of the extractor **M** is connected through a return conduit **69** to a compressor for nitrogen **70** driven by a gas turbine **71**. The closing of this line through which the nitrogen is running is done through a discharge conduit **72** which makes the connection to a tank of liquid nitrogen **P** provided at its superior part with a valve **73** and a lamination valve **f** for adiabatic nitrogen expansion, and at the lower part with an other

valve **74** from which through conduit **75** and entrance valve **63** is done the connection with gas liquefactor **N**.

The exit valve **64** of the cooling serpentine **62** of liquefactor **N** can be connected, either with the entrance valve **56** of serpentine **55** of extractor **M** through a conduit **76**, or with a return conduit **69** through a conduit **77** and a valve **78**.

An other connection, done with the scope of apparatus air purging, according to the invention, is that through which the conduit **60** between the valves **58** and **61** of extractor **M** and respectively liquefactor **N** was connected with the discharge conduit **72** which connects the compressor **70** with entrance valve **73** and the lamination valve **f** of liquid nitrogen tank **P**, connection made through a conduit **79** and a purge valve **80**.

An other conduit **81** and a valve **82** make the connection from the superior part of liquid nitrogen tank **P** and the return conduit **69**, on which is provided a connection **83** for filling with nitrogen gas.

The required electric energy for supplying the electromotors and other electrical subensembles of apparatus, according to the invention, is furnished by some electrical generators **84** placed on each of the guiding arms **A** and driven by gas turbine **71**.

The apparatus for collection of free methane gas from the sea bottom, in an other realization version, according to the invention, has as scope the liquefaction of methane gas by compression, goal achieved with the help of a technological line **Q**. The coming methane gas from water separator **L** through conduit **53** enters through valve **54** in a humidity extractor **R** placed on platform **C**.

The dry methane gas is sucked through a valve **85**, a conduit **86** and then through a valve **87** of a turbocompressor **S**, placed on the guiding arm **A**, from where, after a first compression, is sent through a valve **88** and conduit **89** to run through a cooler **g** placed in the sea water at a level close to its surface. From the cooler **g**, the methane gas is sucked through conduit **90** and through a valve **91** by turbocompressor **T** situated on the same axis with turbocompressor **S**. In the compressor **T** takes place the second step of methane gas compression and from where is discharged through a valve **92** and a conduit **93** towards an other cooler **h**, situated in the same conditions like the cooler **g** under the sea's surface level.

After the second cooling operation the methane gas is sucked through a conduit **94** and through valve **95** by the compressor **U** which does the third step of compression before the liquefaction. From here, the methane gas passes through valve **96** a conduit **97** a valve **98**, after which is laminate through a valve **j** and then is adiabatic expanded passing in the liquid state in a tank **V**, where is being accumulated. From the tank **V** the liquid methane can be delivered to the custumers through conduit **99** and valve **100**.

The turbocompressor **S**, T and **U** are driven by a gas turbine **W** coupled with an air compressor **Z** and with an electrical generator **84**, all these equipment being placed on the guiding arm **A** at the intersection between the horizontal portion **1** and the sloping portion **3**.

The cooling and condensation of water vapors from the humidity extractor **R** is done by sucking through a valve **101** and conduit **102** with the help of an ejector **m** the liquid methane from the tank **V** and then introducing it through a conduit **102** in the humidity extractor **R** in a gaseous state and at a suitable temperature for cooling and condensing the water vapors arrived with the gaseous methane through conduit **53** and valve **54**. The condensate evacuation is done through a conduit **104** and valve **105**.

The transformation of methane from liquid state in a gaseous state takes place in the ejector **m** with the help of hot methane gas arrived through valve **106**, a conduit **107** and through an other valve **108** from the turbocompressor **S**.

The use of technological line **Q** for the methane liquefaction requires an additional attention and safety protection in order to eliminate the possible methane explosion.

Like in the case of other apparatus components, according to the invention, on each from guiding arms **A** and on platforms **B** and **C** is installed a technological line **Q**.

The apparatus, according to the invention, can be brought at the prospective place, where the methane collection will take place, by towing or propelling, or unensembled and then ensembled above the metastabile hydrate gas deposit of which extraction follows.

After its positioning at the desired coordinate by putting it in operation two by two and as much as it is necessary the propellers **8**, **9**, **10** and **11**, it is proceeding to the ensemble alighting, letting first the central anchor **5** with the help of hoist **4** and then on row as two from lateral anchors **7** placed diametrically opposite, with the help of ropes **31** and **36** and the electrical reversible and double trolleys **F** and **G**.

The apparatus, according to the invention, once it is positioned, the trolleys **D** and **E** are put in operation, choosing first the position on a radial direction of water separators **L** the mixing collectors **K** and respectively a flexible conduit **50**, maneuver followed by launching the collectors **K** and conduit **21** until near of the sea bottom, following a good set of legs **49** for giving stability to the collectors **K**.

The pumps **47** are put in operation to suck the water from the inferior room **d** of water separator **M**, water which is accumulated here after the mixture of sea water-methane gas overflows from sleeve **43** and for its continuos evacuation into the sea. In this way it is ensured and controlled a water level, inferior of the upper end of mentioned sleeve **43**. This fact allows, in the first place, the ascendant flow of sea water-methane gas mixture, which is coming from metastabile zone **e** through collector **K** and conduit **21**. This level difference facilitates a lso the water distribution on the entire surface of the horizontal plate **44** for taking place the gravitational separation, due to the difference of the density of methane gas and seawater.

The humid methane gas collected at the superior part of room **c** is sucked by conduit **53**, enter into the humidity extractor **M**, where, due to the serpentine **55** cooled with nitrogen, is taking place the water vapors condensation on this surface and then the water collection and its evacuation through a connection **86** and a valve **59**. The dry methane gas goes out from the extractor **M** through valve **58** and conduit **60**, penetrates through valve **61** and enters into the methane liquefactor **N**, in which is produced its cryogenic liquefaction, due to the contact with the cooling serpentine **62 through** which is running nitrogen.

The liquid methane accumulated at the inferior part of liquefactor **N** is running through valve **65** and **67**, conduit **66** entering into the storage tank **O**, from where its evacuation is done through connection **87** and valve **68**.

The required nitrogen to the liquefactor **N** and the extractor M is introduced in apparatus, according to the invention, in gaseous state through connection **83**, the return conduit **69** towards the compressor **70**, from where is discharged through conduit **72**, valve **73** and lamination valve **f**, where takes place the adiabatic expansion and then in the liquid nitrogen tank **P**. From here, the liquid nitrogen is running through the exit valve **74**,

conduit **75**, entrance valve **63** the cooling serpentine **62** of the liquefactor N and getting warm, gets out in cooled gas state, through valve **64** .

The nitrogen gas is running further through conduit **76**, is crossing entrance valve **56** and enters in cooling serpentine **55** of the extractor **M**, where is being done the water vapors condensation from methane gas and penetrates through exit valve **57** in the return conduit **69** of compressor **70**.

The largest portion of nitrogen gaseous state accumulated at the superior part of the tank **P** is sucked through conduit **81**, valve **82** and through conduit **69** towards the compressor **70**, from where is sent after that, under pressure, through conduit **72**, valve **73** and lamination valve **f** to the tank **P**.

To eliminate the eventual mixing of methane gas with the air and thereof to avoid the peril of major explosion of apparatus, according to the invention, before of any putting in operation it is required the cleaning/purging of air of the line which follows to be traversed by the methane gas through separator **L**, conduit **50** and **53**, the extractor **M** the conduit **60** and **79**, the liquefactor **N**, the conduit **66**, the tank **O** and the conduit **87**. In order to realize this operation, first the valves **54** and **73** have to be closed. Will be then connected the connection **83** to the nitrogen gas tank and then, by putting in operation the compressor **70** it will be filled up the above described line, through the conduit **72**, the conduit **79** until the presence of nitrogen it will be detected at the exit from valves **68** and **59** and then immediately proceeding to the closing of these, to ensure the tightness of the apparatus, according to the invention.

The procedure and the apparatus for the collection of free methane gas from the sea bottom presented with the above description is an example of realization of the invention's principle. Other method of continuos extraction capable to collect and to liquidity the free methane gas from the sea or ocean bottom can be known and presented of those with abilities in the field of continuos extraction. Those other presentations of continuos extraction, because they use the principles of the present invention, have the tendency to fall in the frame of appended claims. Also, those with competence in the field can realize from the above description of the present invention the improvements, changing and modification. These changes and modifications will be perceived then as being comprised in the area of the protection of the following claims.